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Micro-Submersible Lake Exploration Device

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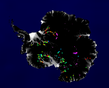
Abstract

The Micro-Subglacial Lake Exploration Device (MSLED) is currently being designed by the Jet Propulsion Laboratory (JPL) to be deployed with the National Science Foundation (NSF) in subglacial Lake Whillans in an upcoming field season. An eight inch borehole will be drilled in the Whillans ice stream as the MSLED, attached to the Antarctic Ice Borehole Probe (IBP), will descend into the subglacial lake. As both instruments reach the lake, the MSLED will separate from the IBP and have the capability to roam independently in the lake with a one kilometer operating range. The primary goals of the MSLED are to provide in-situ measurements of temperature, pressure, and conductivity as well as supply high resolution real-time video from the MSLED to the ground station to conduct remotely operated investigations. The MSLED will provide two-way communications to the surface and have an operating time of a minimum of 2.5 hours. Presently, the MSLED is in the design phase. This poster outlines the scientific background that inspired the project, the deployment method, and finally, detailed information on the individual subsystems within the MSLED.

Whillans Ice Stream in West-Antarctica

Science

Recent investigations and mappings of subglacial lakes in West Antarctica by satellite laser altimetry and satellite radar interferometry have shown the existence of at least 145 subglacial lakes beneath the Antarctic ice shelf, which may have an impact on the covering ice sheet. Understanding the movement of ice flow and the ice-water interaction is imperative to predicting the future of ice sheets and their effect on rising sea levels. According to the 2007 report of the Intergovernmental Panel on Climate Change, a poor understanding of ice sheet dynamics and ice sheet vulnerability to oceanic and atmospheric warming are the greatest uncertainties of assessing future global seal level rise. Especially processes at the basal ice sheet boundary and at the ice-ocean interface that govern the rate of ice loss to the ocean are still insufficiently understood to be incorporated into ice sheet models. The other avenue of exploration is to gain information on the subglacial biotic ecosystem. Studies illustrate that the subglacial environment is an ecosystem with the potential to impact our understanding of global biogeochemical cycles, astrobiology, and the biodiversity of cold, aquatic, dark environments. Furthermore, with the prospect of subglacial aquatic environments on Jupiter's moon Europa, a strong foundation of knowledge is necessary for successful extra-terrestrial exploration, for which Antarctica provides an excellent analog environment.



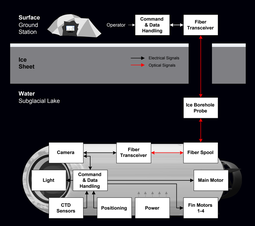
Active Subglacial Lakes, Antarctica
Smith et al., 2009

Icy Crust of Jupiter's Moon Europa

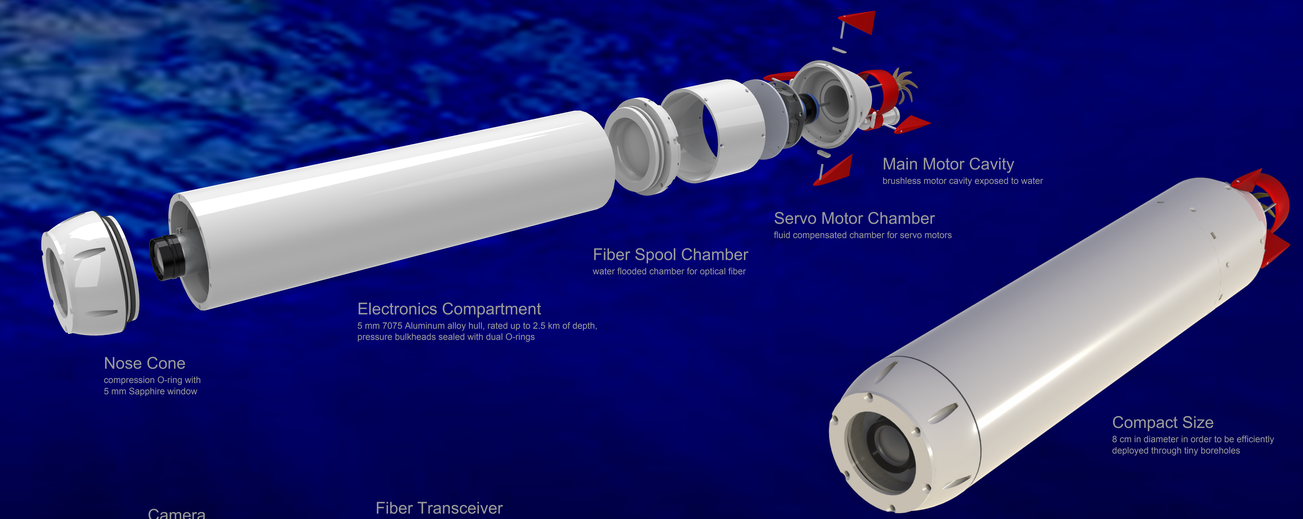
System Overview

The vehicle's mechanical structure is divided into several sections that provide habitats for different types of components: The nose cone and main hull provide a pressure-resistant water-tight housing for electronic and optic components. A water-filled chamber will house the optical fiber spool that will be deployed via a shaft through the main propeller. Four servo motors are located within a housing that is compensated with non-conducting liquid. The main motor cavity again is flooded with water thanks to the use of a brushless motor. The tail cone further holds the kort nozzle with propeller and the CTD sensor.

The internal components on board transmit and receive data simultaneously over a single fiber optic cable that is interfaced with the surface via the Ice Borehole Probe. The vehicle is managed by a 16 MHz microcontroller that carries out ground station commands and is capable of providing a certain degree of autonomy, controlling camera, light, fins, propulsion and power management. The microcontroller further receives salinity, temperature, depth, possible other biochemical and vehicle status data, which are packetized along with a high-quality video stream onto a Gigabit Ethernet connection for transmission to the surface.



MSLED System Diagram


Nose Cone
compression O-ring with 5 mm Sapphire window
Electronics Compartment
5 mm 7075 Aluminum alloy hull, rated up to 2.5 km of depth, pressure bulkheads sealed with dual O-rings
Fiber Spool Chamber
water flooded chamber for optical fiber
Main Motor Cavity
brushless motor cavity exposed to water
Servo Motor Chamber
fluid compensated chamber for servo motors
Compact Size
8 cm in diameter in order to be efficiently deployed through tiny boreholes
Camera
2/3" CCD image sensor for low lighting conditions, LED scene illumination, 20 fps, 1360 x 1024 px, 41.6025 µm² sensor element area
Fiber Transceiver
bidirectional Gigabit Ethernet fiber transceiver, transporting high-resolution video, senor data and vehicle commands over one single optical fiber
Motor Speed Controller
motor control via Command and Data Handling system
Inertial Measurement Unit
orientation resolution smaller than 0.1 degrees, Attitude and Heading Reference System (pitch, yaw, roll)
Battery Pack
eight Lithium-Thionyl (Li-SOCl2) batteries, minimum runtime 2 hours
Main Motor
brushless motor for in-water operation
Command & Data Handling
microcontroller with 16 million instructions per second, 256 KByte of Flash, 4 KBytes of EEPROM, 8 KBytes of SRAM, transmit sensor data to surface, execute vehicle commands
Propulsion
submarine propeller included in kort nozzle for efficient propulsion
Fiber Spool
1.5 km precision-wound optical fiber, single-mode, non-kink deployment, strong tether, for bidirectional data communication
CTD Sensor
one device measuring salinity, temperature and depth in situ
Steering Fins
controlled by four independent servo motors

Mission Summary

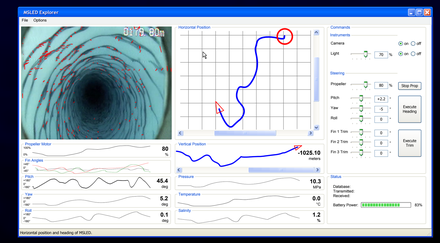
The objective of the MSLED mission is to explore subglacial aquatic environments while gathering high-quality video as well as temperature, salinity, depth and potentially further sensor data. The lakes have to be accessed through boreholes with diameters of eight inches.

Tethered to the existing Ice Borehole Probe developed at JPL, the MSLED will have the capability to roam freely within a range of 1 km and be safely brought back to the surface. MSLED shall

- provide high resolution video to the surface in real-time.
- perform in-situ measurements of temperature, salinity and pressure.
- carry 1.5 km of optical fiber.
- allow an operational range of 1 km once deployed within the lake.
- operate at a depth of down to 2.5 km.
- maximum 8 cm in diameter in order to be compatible with the borehole diameter as well as docking station of the Ice Borehole Probe.
- operate within the borehole for a minimum of 2 hours.
- establish two-way communications to the surface with sufficient band-width to transmit instrument data and high definition video in real-time.
- return to the docking station for retrieval.
- operate in temperatures between -10°C and +50°C

Ground Station

The vehicle will be operated from a ground station that visualizes and records the captured raw and processed data, such as video, heading and sensor data as well as the vehicle's status data. The ground station provides full vehicle control, including camera, lighting, fins and pro-peller. Thanks to virtually unlimited space and power on the surface, no constraints in computing capabilities are imposed to the ground station. Therefore, computing intensive algorithms, such as visual odometry using the high-resolution video or semi-autonomy using all available sensor data, can be outsourced to a distributed system. If required in the future, low-power hardware autonomy can be developed for specific missions, such as to Jupiter's moon Europa.



Acknowledgements & Contact

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